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Survey of Transmissometers Used in Conducting Visible Emissions Training Courses

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16. ABSTRACT

The Quality Assurance Branch (QAB) of the Environmental Monitoring and Support Laboratory has undertaken the task of evaluating the transmissometers that are currently being used in visible emissions training programs. The criteria used in the evaluation were the design and performance specifications for smoke meters promulgated in the November 12, 1974, Federal Register.

Sixteen "smoke schools" from EPA Regions 1-8 participated in the survey which was performed between April 21, 1977, and August 2, 1977.

Results of the survey showed that only half of the transmissometers which were evaluated met all of the design and performance specifications. A lack of operator understanding and familiarity with smoke generators was a contributing factor among those units that failed to meet the requirements.

A list of recommendations are, also, included for a five-phase special study that would attempt to improve the training program for smoke inspectors.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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SURVEY OF TRANSMISSOMETERS

USED IN CONDUCTING

VISIBLE EMISSIONS TRAINING COURSES

by

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MARCH 1978

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The many generator operators who assisted us in the evaluation of their transmissometers have contributed significantly to the success of this survey and for their time and efforts we are grateful.

SECTION 1

INTRODUCTION

HISTORY

Visible emissions training using a smoke generator and a transmissometer was initiated in 1950 by the Los Angeles County Air Pollution Control District (1). Since that time some notable modifications and additions have been made to this approach in training inspectors to "read smoke", however, the instrumentation required to train inspectors has remained practically unchanged.

The U. S. Environmental Protection Agency (EPA) specified the procedures involved in visible emissions training with the promulgation of Method 9 in the Federal Register on December 23, 1971 (2). According to the Method,

> "to certify as an observer, a candidate must complete a smokereading course conducted by EPA, or equivalent."

During the early seventies, EPA through the Air Pollution Training Institute conducted numerous "Visible Emissions Certification or Recertification" courses throughout the United States. However, because of the need for recertification every 6 months and the travel restrictions placed on many state and local agency inspectors, several states and cities attempted to set up equivalent courses. Many questions quickly surfaced concerning what constituted an equivalent course.

To clarify this point, Method 9 was revised and expanded on November 12, 1974 (3). Included in this revision was a list of smoke meter or transmissometer design and performance specifications. Each state or local agency was expected to meet these established criteria.

PURPOSE

When a survey of transmissometers used in conducting visible emissions training courses was planned, over 2 years had already passed since the transmissometer design and performance specifications had been published. This was sufficient time to expect all existing visible emissions training transmissometers to be modified and operating according to the design and operating specifications. However, discussions with the EPA Environmental Sciences Research Lab, the Office of Air Quality Planning and Standards, and a smoke generator manufacturer revealed that not all of these smoke reading courses met the outlined criteria set forth in the November 12, 1974, Federal Register.

Thus, there was a need to identify those generators that did not meet these criteria and to determine why they did not meet these criteria. Since there were more smoke schools in existence throughout the country than could be surveyed economically, the decision was made to choose two schools from each EPA Region. This would be a sufficiently large number for evaluation and would provide data that was not regionally biased. Such a survey promised to answer two questions. First, are the visible emissions training transmissometers across the country accurately measuring the opacity in the smoke generator or are some of them operating with a built-in bias? Second, are all of the schools concerned about calibration procedures, or are some of the schools careless in performing regular checks on their equipment?

SECTION 2

PROCEDURES

DATA REQUIREMENTS

In planning the survey, the first decisions that had to be made involved the identification of information required from the survey participants and their instruments and the methodology for obtaining this information. Since the smoke generator specifications mentioned in the November 12, 1974, Federal Register were limited in scope to the smoke meter or transmissometer, we concluded that our survey should also be limited to the instrument that measured the smoke opacity. This approach had the advantage of not requiring that each generator be fired during the field evaluation of the transmissometer. One disadvantage of not including parts of the generator other than the transmissometer was that our survey would not reveal problems in maintaining a consistent burn over the entire 0 to 100% opacity range. If obtaining a consistent burn was a problem, however, the generator operator would already be aware of it. Little would have been gained from identifying problems that were already well known. By eliminating other components from the evaluation, each transmissometer could be tested in the time span of an hour provided the instrument was warmed up before the test began. Considering that participation in this survey was on a voluntary basis, a shortened test time was desirable.

With the study limited to the transmissometer, the question then became, what transmissometer operating characteristics were of interest? It was decided (as shown in Table 1) to study the smoke meter design and determine if the performance specifications enumerated in the November 12, 1974, Federal Register were met.

TABLE 1. SMOKE METER DESIGN AND PERFORMANCE SPECIFICATIONS

	Parameter	Specification
a.	Light source	Incandescent lamp operated at nominal rated voltage (± 5% nominal rated voltage)
b.	Spectral response of photo cell	Photopic (daylight spectral response of the human eye)
c.	Angle of view	15° maximum total angle
d.	Angle of projection.	15° maximum total angle
e.	Calibration error	± 3% opacity, maximum
f.	Zero and spandrift	± 1% opacity, 30 min
g.	Response time	5 sec

Having identified what we should expect from the transmissometers, our task became one of finding methods to check each of these parameters to see whether the design or performance specifications were being met.

Light Source

Devising a method to check the light source was relatively easy. A voltmeter could be placed across the incandescent lamp and the measured voltage compared with the nominal rated voltage listed in the smoke meter specifications. The voltmeter had to handle a wide range of AC and

DC voltages because of the large variety of voltage requirements encountered among the instruments being surveyed. Instrument specifications were not always available to determine the nominal rated voltage of the lamp. When specifications were not available, the generator operator could usually provide the needed information.

Spectral Response of Photocell

Determining if the photocell would yield a photopic response required either checking the spectral response curve of the specific commercial photo emissive surface as listed in the literature (4) or measuring the spectral response curve by using wavelength specific filters. The latter approach was used for the following reasons:

- Some of the photocells were old, and the spectral response may have changed with time.
- Some of the transmissometers had undergone major modifications; therefore, the photocell might have been different from the one listed in the manufacturer's specifications.
- The manufacturer's spectral response curve data may have been suspect.
- Instrument specifications identifying the photocell may not have been available.

To test for photopic response a series of five Kodak Wratten sharp cut-off filters were used. The filters used blocked out practically all light at, and below, a specific wavelength. By choosing five different filters it was possible to stepwise block out light going from left to right on the visible spectrum. The fifth filter was a visibly opaque

filter which allowed only infrared light through. Using the spectral response curves provided by Kodak (5) shown in Figures 1-5, the wavelength was determined at which 95% of the light was blocked out. This wavelength was then plotted against the observed transmissometer response obtained with this filter to get a spectral response curve for each transmissometer. This curve, generated from the set of five filters, was compared with the standard spectral-luminosity curve for photopic vision (6). Filter No. 1A consistently blocked out some visible light and was therefore a poor choice for this survey. The other filters, however, performed satisfactorily.

Angles of View and Projection

Unlike checking the photopic response, measuring the angles of view and projection could not be readily achieved without taking the instrument apart. The Federal Register provided equations for calculating both angles but to do so required measuring the length or width of various components of the instrument. These dimensions were not readily accessible once the generator was placed in operation. Measurement of these angles, therefore, was omitted from the survey procedures since taking the transmissometer apart to make these measurements could have resulted in damage to the instrument.

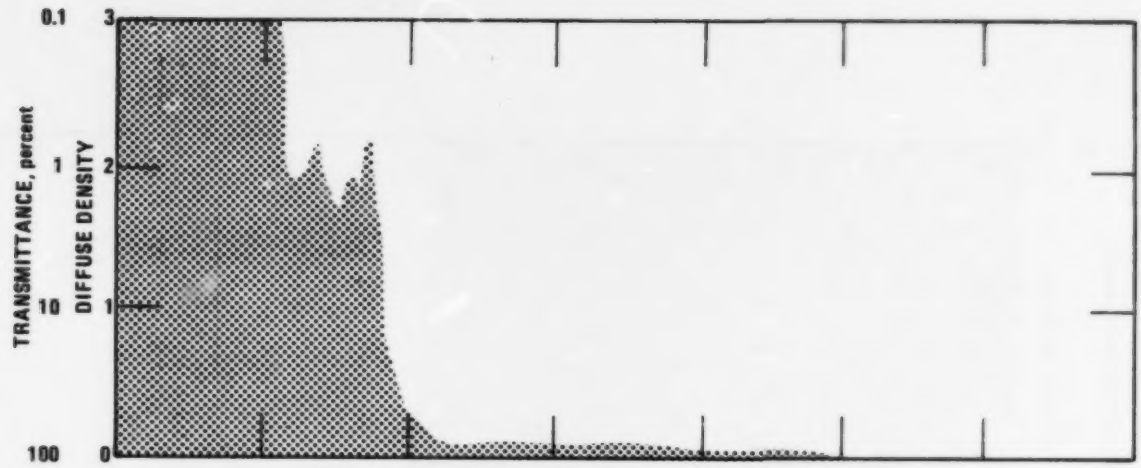

Figure 1. Response curve for filter no. 1A.

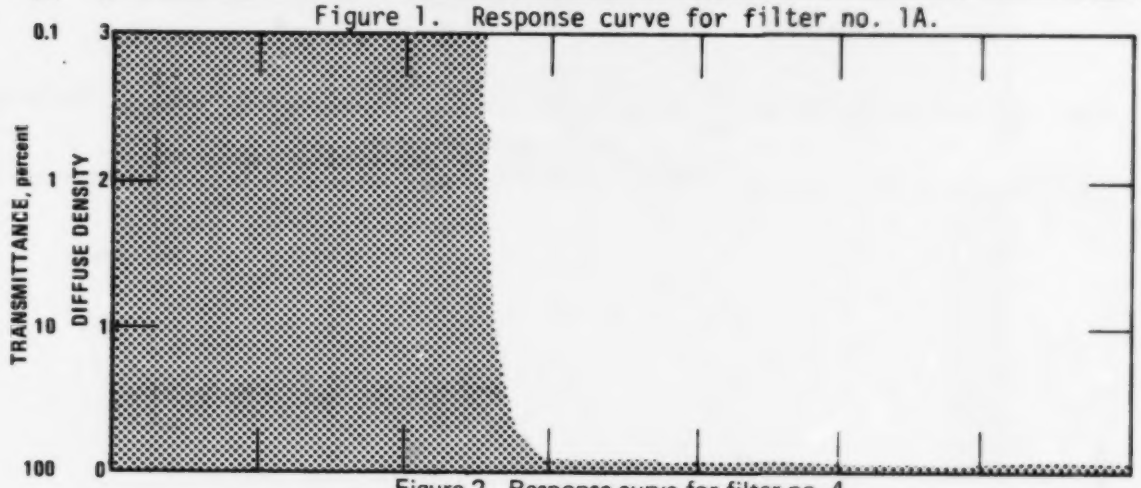

Figure 2. Response curve for filter no. 4.

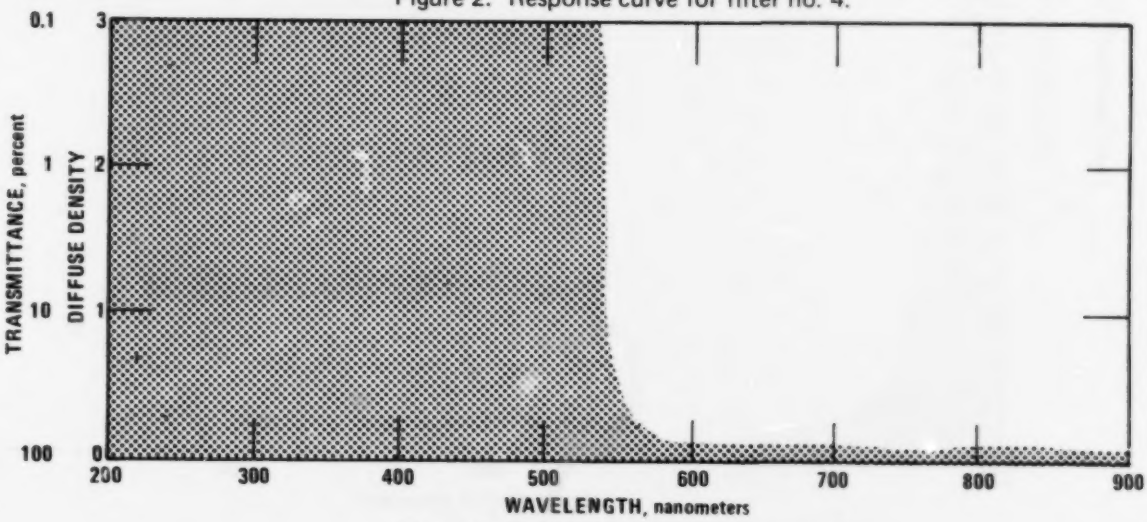

Figure 3. Response curve for filter no. 21.

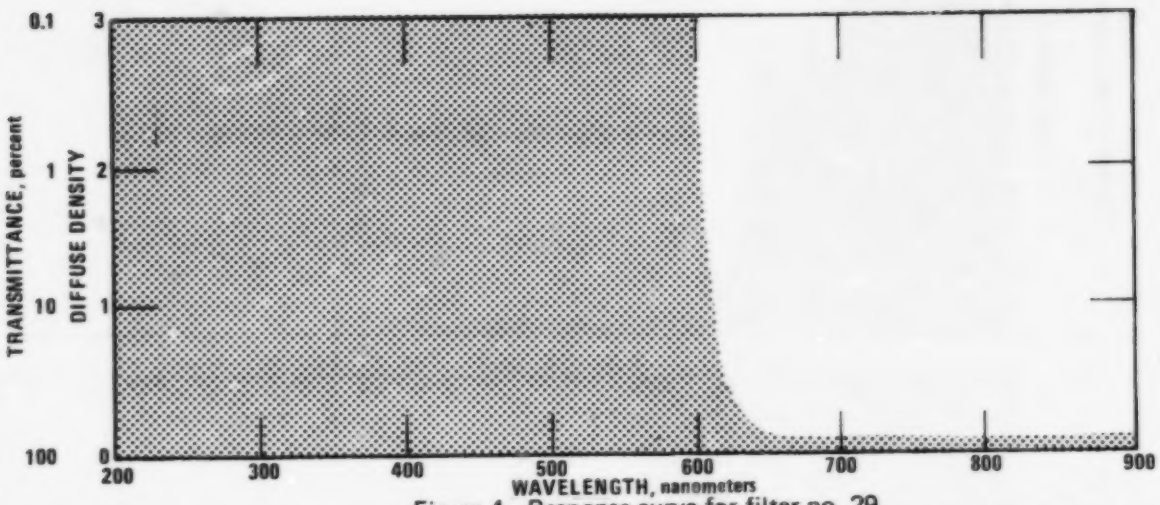

Figure 4. Response curve for filter no. 29.

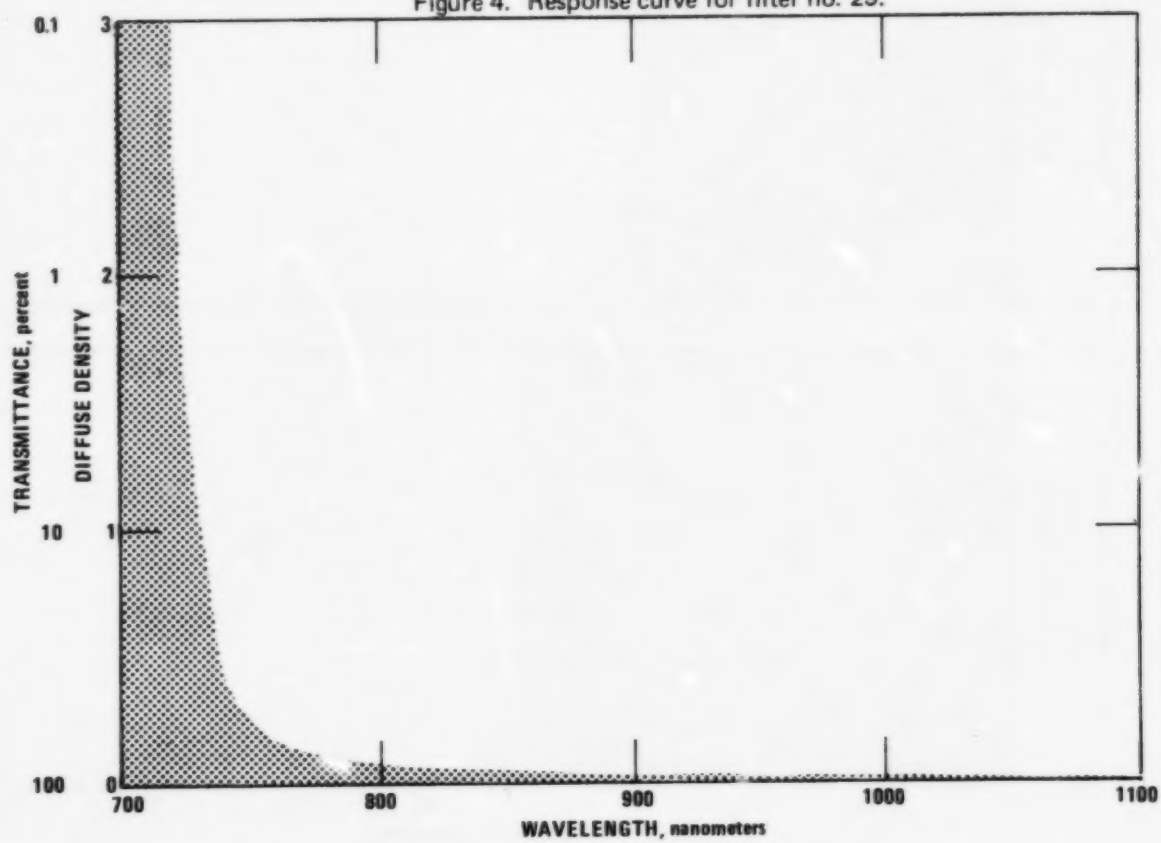

Figure 5. Response curve for filter no. 88A.

Calibration Error

The calibration of the transmissometer according to the Federal Register method was to be achieved by introducing neutral density filters of nominal opacities of 20, 50, and 75 percent. Two choices of neutral density filters are readily available. One is the gelatin-type filter commonly available from Kodak, and the other is described as a metal-film filter available from Tiffen. Although the gelatin filter has been used almost exclusively in calibrating smoke generators, it is not a true neutral density filter. Over the range of 500 to 400 nanometers, the light transmission of the gelatin filters drops almost in half (7). This can be compared to the relatively uniform light transmittance of the metal-film filters listed in Tables 2-4 (8). Prepared with this information, we chose to use the three metal-film filters supplied by Tiffen to perform the calibrations.

Three different approaches have been used to introduce the filters into the light path. The simplest but probably the worst approach is to remove the photocell, tape the filter to it, and put the photocell back onto the transmissometer. This method of calibration presents the following problems:

- For those photocells that screw onto the transmissometer arm, the potential exists for not getting the photocell screwed back into the same position after each calibration.
- Metal-film filters are usually too large to tape onto the photocell; therefore, gelatin filters must be used.
- Because of the shape of the photocell, gelatin filters are usually bent when taped to the photocell. This could affect the opacity

reading.

. Taping the filters securely to the photocell is difficult without placing the tape in the light path.

The second method of introducing the filter is by cutting a slot in either the photocell arm or light source of the transmissometer and lowering the filter into the light path. This method is commonly used by generator operators who have had to modify their equipment to do calibrations.

The best alternative method for introducing the filter is to insert it down the stack directly into the light path. This requires a special tool known as a calibration wand (Figure 6). The wand is long enough to be inserted from either end of a collapsible-stack generator. The wand has a black metal, two-prong fork at one end which fits around the transmissometer cross-bar inside the stack and secures the wand in place. Inside the two-prong fork is a black metal filter support with a 1-1/2 inch diameter round hole in it. The filter support

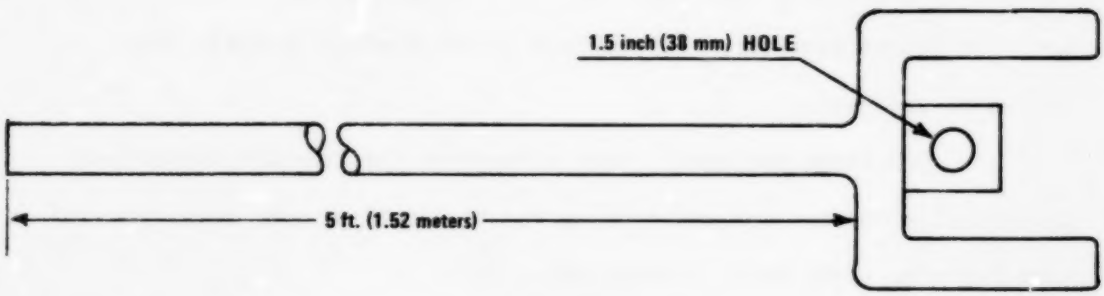

Figure 6. Calibration wand.

TABLE 2. SPECTRAL TRANSMITTANCE OF TIFFEN FILTER ND 0.1

Wavelength (nm)	Transmittance (Percent)	Optical Density
380	73.1	0.136
390	74.0	.131
400	74.5	.128
410	74.7	.127
420	74.8	.126
430	74.9	.125
440	75.2	.124
450	75.4	.122
460	75.7	.121
470	75.9	.120
480	76.0	.119
490	76.0	.119
500	76.2	.118
510	76.3	.117
520	76.4	.117
530	76.6	.116
540	76.8	.115
550	76.5	.116
560	76.7	.115
570	76.8	.115
580	77.0	.114
590	76.6	.116
600	76.6	.116
610	76.7	.115
620	76.6	.116
630	76.7	.115
640	76.6	.116
650	76.4	.117
660	76.4	.117
670	76.3	.118
680	76.2	.118
690	76.0	.119
700	76.0	.119
710	75.9	.120
720	75.6	.122
730	75.7	.121
740	75.6	.122

TABLE 2. SPECTRAL TRANSMITTANCE OF TIFFEN FILTER ND 0.1 (continued)

Wavelength (nm)	Transmittance (Percent)	Optical Density
750	75.2	.124
760	75.2	.124
770	75.1	.124

TABLE 3. SPECTRAL TRANSMITTANCE OF TIFFEN FILTER ND 0.3

Wavelength (nm)	Transmittance (Percent)	Optical Density
380	46.7	0.331
390	47.3	.325
400	47.6	.323
410	47.7	.322
420	47.7	.321
430	47.7	.322
440	47.7	.322
450	47.7	.321
460	47.8	.320
470	47.8	.320
480	47.9	.320
490	47.9	.319
500	47.9	.319
510	48.0	.319
520	48.0	.319
530	48.0	.319
540	48.1	.318
550	48.1	.317
560	48.2	.317
570	48.1	.318
580	48.2	.317
590	48.2	.317
600	48.2	.317
610	48.1	.318
620	48.2	.317
630	48.2	.317
640	48.2	.317
650	48.2	.317
660	48.2	.317
670	48.2	.317
680	48.2	.317
690	48.2	.317
700	48.2	.317
710	48.3	.317
720	48.2	.317
730	48.2	.317
740	48.2	.317

TABLE 3. SPECTRAL TRANSMITTANCE OF TIFFEN FILTER ND 0.3 (continued)

Wavelength (nm)	Transmittance (Percent)	Optical Density
750	48.2	.317
760	48.2	.317
770	48.2	.317

TABLE 4. SPECTRAL TRANSMITTANCE OF TIFFEN FILTER ND 0.6

Wavelength (nm)	Transmittance (Percent)	Optical Density
380	23.6	0.628
390	23.7	.625
400	23.7	.625
410	23.6	.627
420	23.5	.629
430	23.4	.630
440	23.3	.633
450	23.1	.636
460	23.0	.639
470	22.8	.641
480	22.7	.654
490	22.6	.646
500	22.4	.649
510	22.3	.651
520	22.1	.655
530	22.1	.656
540	22.0	.658
550	21.9	.659
560	21.8	.661
570	21.7	.663
580	21.7	.664
590	21.5	.667
600	21.4	.669
610	21.4	.670
620	21.3	.672
630	21.3	.672
640	21.2	.674
650	21.1	.676
660	21.0	.677
670	21.0	.678
680	20.9	.679
690	20.8	.681
700	20.8	.683
710	20.7	.684
720	20.7	.685
730	20.6	.685
740	20.5	.688

TABLE 4. SPECTRAL TRANSMITTANCE OF TIFFEN FILTER ND 0.6 (continued)

Wavelength (nm)	Transmittance (Percent)	Optical Density
750	20.5	.689
760	20.4	.690
770	20.2	.695

is just wide enough to fit through the slit in the transmissometer cross-bar. Due to the wide range of instrument designs encountered in this study, eight different filter supports were prepared in increasing size increments of 1/8 inch. With this calibration wand we were able to introduce our metal film filters across the light path and measure the calibration error.

Zero and Span Drift

The Federal Register specifies that zero and span drift be determined only after operating the smoke generator in a normal manner for 1 hr. A problem arose, however, in defining normal operation. Some generator operators interpreted this to mean that the instrument may be re-zeroed and re-spanned after every new reading. Since normal operation was not officially defined, the operators' definition could not be disputed.

The technique used in this survey to measure zero and span drift was to perform the other checks which have already been mentioned and to follow this with a zero and span check. Whether the operator had re-zeroed and re-spanned his instrument during these earlier checks was not taken into consideration. It is not likely, however, that the operator was able to anticipate when the zero and span drift were going to be checked.

Response Time

The last test performed on the transmissometer was for response time. A variety of instruments were being used to register the measured opacity. They included such extremes as a simple dial gage, a strip chart recorder, and a digital recorder. With the dial gage it was difficult to discern opacity readings in less than 5-% increments. The digital recorder had the problem of being barely visible in the bright sun. In general, the strip chart recorders presented the fewest problems, although some of the recorders gave an unacceptably slow response. Response time was measured by a stop watch over the range from zero to span.

OBTAINING PARTICIPANTS

Although our initial goal was to obtain two participants from each EPA Region, this was modified during the early phases of the survey due to restrictions in our travel budget. The two west coast Regions, Regions 9 and 10, were eliminated from the survey because they represented the greatest strain on travel time and money. Representatives from the other eight Regional Offices were requested to submit a list of smoke reading courses being scheduled in their Regions along with the name of a contact person for each school.

The criteria used in selecting survey participants included determining whether;

- The survey could be scheduled either before or after a planned "*smoke school*".

- A large number of smoke inspectors were trained annually with that particular generator.
- The design of the generator was conducive to being surveyed.
- The generator operator was willing to have his transmissometer tested.

Each of the agencies that ultimately participated did not have to meet all of these criteria; however, the criteria did aid in the selection of two candidates from each Region.

Table 5 lists those agencies that were selected and did participate in the survey. Since their participation was voluntary, each agency has been asssigned a random code number to prevent the agency from being identified with a specific set of test results.

TABLE 5. SURVEY PARTICIPANTS

1.	EPA Region I in Boston, Massachusetts
2.	State of Connecticut
3.	State of New York
4.	EPA Region II in New York, New York
5.	City of Pittsburgh, Pennsylvania
6.	State of Virginia
7.	EPA Region IV in Athens, Georgia
8.	State of North Carolina
9.	City of Chicago, Illinois
10.	State of Minnesota
11.	State of Arkansas
12.	State of Texas
13.	EPA Region VII in Kansas City, Kansas
14.	State of Iowa
15.	State of Colorado
16.	State of Utah

SECTION 3

SURVEY RESULTS

The survey was conducted between April 21, 1977, and August 2, 1977. All of the tests in the survey were performed by the principal author using the audit tools outlined in an earlier section. Tables 6-10 and Figures 7-9 are summaries of the tests performed on each parameter of the transmissometers.

TABLE 6. LIGHT SOURCE VOLTAGE

Generator Number	Rated Voltage	Measured Voltage	Generator Number	Rated Voltage	Measured Voltage
101	12	12.7	109	110	105
102	110	135	110	24	15
103	110	125	111	12	14
104	12	8.7	112	6	4.8
105	12	12	113	12	13.5
106	NA	6.5	114	12	13.5
107	6	6	115	12.5	14.5
108	NA	7.9	116	12	13.5

TABLE 7. PHOTOPIC RESPONSE COMPARISON

Kodak Filter No.	1A	4	21	29	88A
Generator No.			Opacity, %		
True Photopic	0	5	50	81	100
101	10	11	34	66	93
102	15	11	41.5	87.5	100
103	12	10	41	87	100
104	9.5	8	42	88	99
105	11	15	40	75	93
106	5	14	10	20	32
107	13	9.5	42	87	100
108	15	10	40	85	100
109	12.5	12	36	64	93
110	8	12	38	72	95
111	12	35	66.5	87.5	90.5
112	13	14	25	56	90
113	12	14	37.5	69	92.5
114	11	13	38	70.5	93
115	9.5	10.5	32	63.5	90.5
116	14	11	44	87.5	96

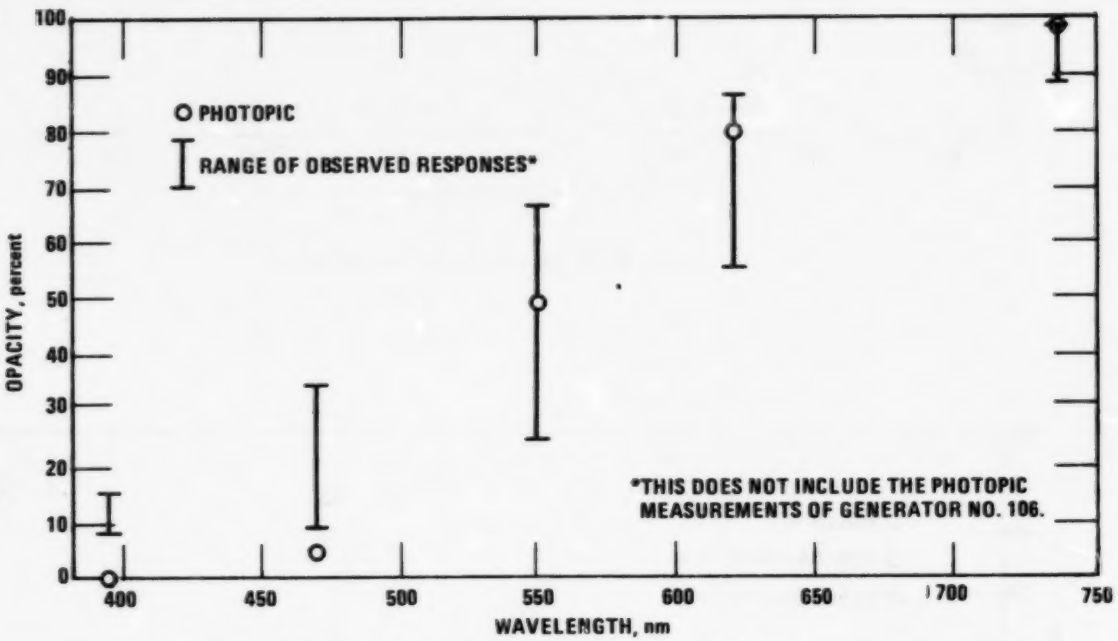

Figure 7. Range of transmissometer responses over the visible spectrum.

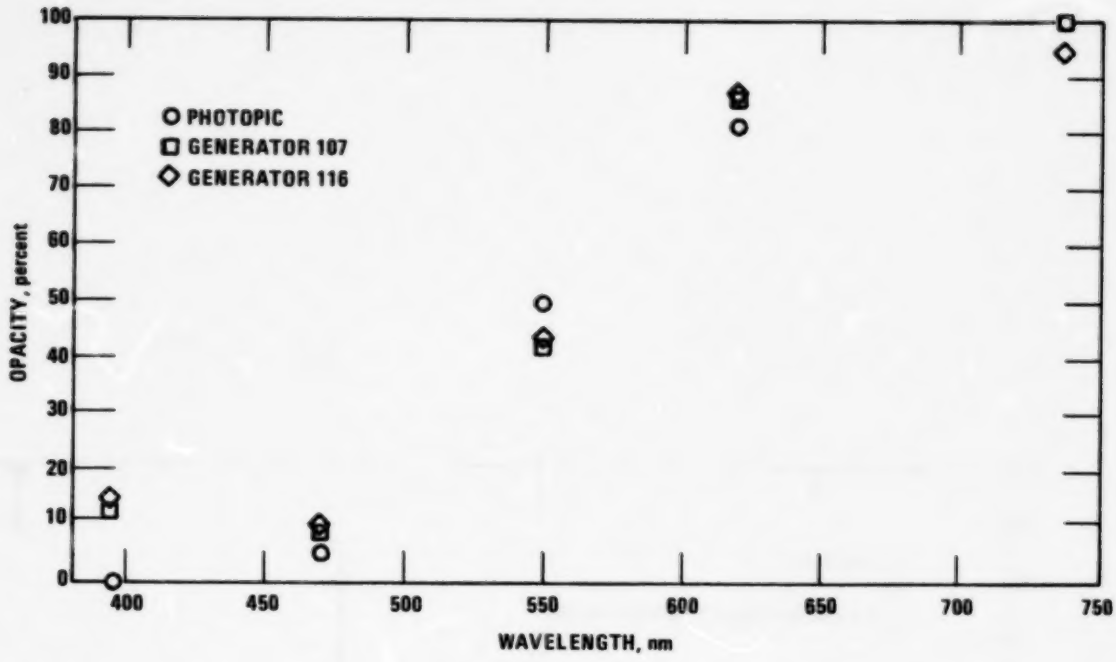

Figure 8. Good photopic comparison.

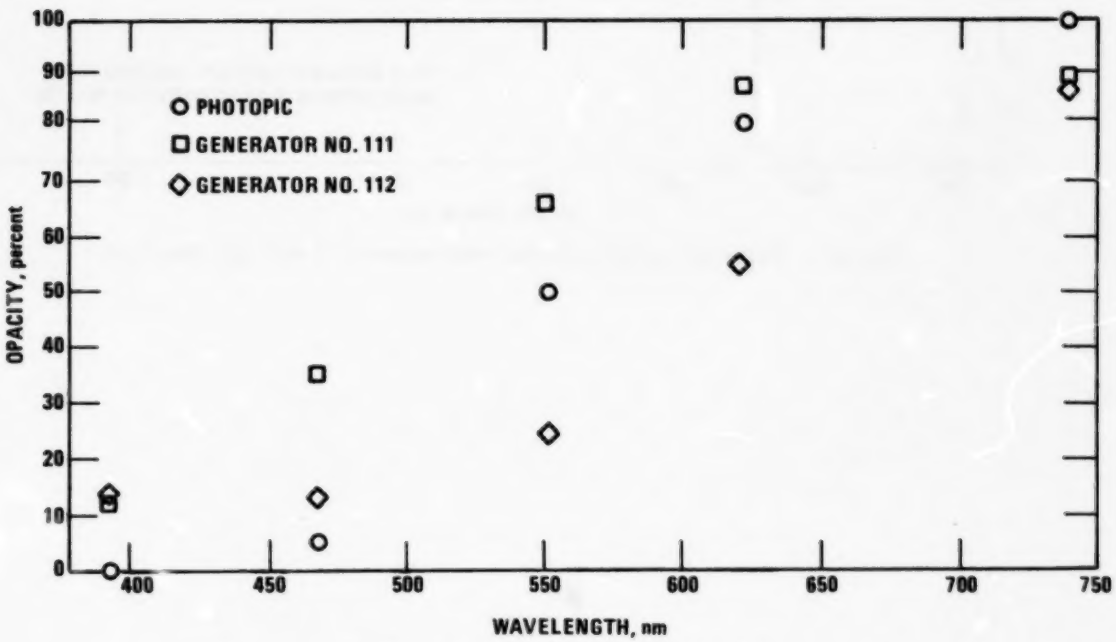

Figure 9. Poor photopic comparison.

TABLE 8. CALIBRATION FILTER CHECK

Generator No.	N.D. 0.1		N.D. 0.3		N.D. 0.6	
	Opacity	% Error	Opacity	% Error	Opacity	% Error
NBS-550 nm	23.5	--	51.5	--	78.5	--
101	23	-0.5	50.5	-1.0	78	-0.5
102	22	-1.5	49.5	-2.0	78	-0.5
103	23.5	0.0	51	-0.5	78	-0.5
104	22	-1.5	49	-2.5	76	-2.5
105	24	+0.5	52	+0.5	79	+0.5
106	25	+1.5	55	+3.5	82	+3.5
107	23.5	0.0	52.5	+1.0	78.5	0.0
108	23	-0.5	51	-0.5	80	+1.5
109	25	+1.5	50	-1.5	75	-3.5
110	19	-4.5	42	-9.5	72	-6.5
111*	21.5	-0.5	56	0.0	81.5	-0.5
112+			44	-7.5		
	24	+0.5	58	+6.5	83.5	+5.0
113	25	+1.5	54	+2.5	81	+2.5
114	23.5	0.0	52	+0.5	79	+0.5
115	21.5	-2.0	50.5	-1.0	79	+0.5
116	26	+2.5	54	+2.5	80	+1.5

*Different filters were used to check this unit because slit size was too narrow for 2-inch metal film filters.

+This instrument had a significant drift problem. The lower opacity was observed at the beginning of the test and the higher opacity about an hour later.

TABLE 9. ZERO AND SPAN DRIFT

Gen. No.	Zero Drift %	Span Drift %	Gen. No.	Zero Drift %	Span Drift %
101	1/2	1/2	109	0	0
102	3	0	110	0	0
103	0	0	111	0	1/2
104	0	1/2	112	14	5*
105	0	1	113	0	0
106	0	0	114	0	0
107	1/2	0	115	1	0
108	3	1	116	1/2	1/2

*The recorder was pegged at approximately 105% opacity.

TABLE 10. RESPONSE TIME

Generator	Response Time (sec.)	Generator	Response Time (sec.)
101	17	109	2
102	3	110	3
103	1	111	4
104	1	112	3
105	4	113	3
106	4	114	4
107	3	115	5
108	1	116	5

SECTION 4

DISCUSSION OF RESULTS

GENERAL

Table 11 is a summary of the transmissometers that failed to meet the performance specifications outlined in the Federal Register. Over one-half of the survey participants failed to meet at least one of these specifications.

Although operator understanding and familiarity with the smoke generator was not measured quantitatively, a subjective evaluation was made. Of the generators that failed to meet the operating specifications, most had operators who lacked a basic knowledge of how the equipment worked. This was not true, however, of the operators of the units that passed all the checks.

As one might expect, the smoke meters receiving more use over the course of a year generally performed better than those used only sporadically. A few of those used most regularly, however, did fail concerning at least one parameter.

TABLE 11. SUMMARY OF SURVEY RESULTS

M - Missing Data

F - Fail

Generator	Light Voltage Deviation +	Light Voltage Deviation -	Spectral* Response	Calibration	Response Time	Zero/ Span Drift	Overall+
101	F				F		F
102	F					F	F
103	F						
104		F					F
105							
106	M		F	F			F
107							
108	M					F	F
109				F			F
110		F		F			F
111	F		F				F
112		F	F	F		F	F
113	F						
114	F						
115	F						
116	F						

* If any reading exceeded photopic opacity value by ± 20 percent, opacity unit failed.

\+ Did not consider unit to fail specifications if positive deviation of light source voltage exceeded Federal Register specifications.

BY PARAMETER

Light Source

Each incandescent lamp was to be operated within ± 5% of the nominal rated voltage according to the Federal Register. This requirement was determined to be too restrictive based on available instrumentation. The only problem that will be encountered by exceeding the nominal voltage is a shorter life for the lamp. Although this is not desirable, if the operator is willing to stock a sufficiently large number of replacement lamps, no real performance failures can be expected. If, on the other hand, the lamp is operated at lower than rated voltage, the instrument may not give an adequate response. Four of the smoke meters surveyed were operating with lamps at less than the nominal rated voltage. Table 6 lists the nominal rated voltage and the measured voltage for all 16 instruments surveyed.

Spectral Response of Photocell

In order for the photocell to be classified "photopic", the Federal Register requires that the "spectral sensitivity of the cell closely approximate the standard luminosity curve for photopic vision. Since there was no definition given for "close approximation", the classification of a photocell as photopic was difficult. Certainly, some photocells were more photopic than others as can be observed by comparing Figures 4 and 5. If any observed reading exceeded the photopic opacity reading by ± 20%, the transmissometer was assumed to fail the performance specification.

The survey disclosed one photocell that could not in any way be classified as photopic. Generator No. 106 was found to have a photocell which was clearly infrared sensitive. The effect of such a photocell is to produce very low opacity readings for very high plume opacities. This effect can be most dramatically observed in the production of white (oil) plumes (9). The discovery that this photocell was being used on a regular basis in smoke reading courses is believed to be the most significant finding of this study.

Calibration Error

Of the 16 generators only 4 failed to meet the ± 3% calibration error specification. In all four cases, the calibration error was less with the lower optical density filters.

Generator No. 106 was only slightly out of calibration with two of three neutral density filters. Both filters read consistently 3-1/2% high. Generator No. 109 was high on only the 0.6 neutral density filter.

Generator No. 110 read consistently low with the greatest error occurring at what should have been the mid-scale reading. Surprisingly, the instrument calibrated perfectly if the filters were introduced into the arm of the transmissometer. When introduced into the center of the stack, the filters read up to 9-1/2% low. This was the only instance in which different readings were obtained in the arm and in the stack. One possible explanation of this difference is that light scattering by the neutral density filters may have occurred when they were placed in the transmissometer arm. This problem is currently being investigated.

Generator No. 112 obtained readings that varied considerably because of a significant positive drift problem. At the beginning of the test, the instrument recorded a value of 44% opacity for a 0.3 N.D filter. At the end of the test when this same filter was reinserted it read 58% opacity or 14% higher. Therefore, the observed calibration problem may have been due entirely to this large positive drift.

Zero and Span Drift

Only three generators did not meet the ± 1% zero and span drift requirement. Two of these generators did meet the span drift requirement but not the zero drift requirement. The only really bad drift was by Generator No. 112, but this was reported previously in the discussion of calibration error.

Response Time

Generator No. 101 was the only one that failed to meet the 5-sec response time requirement; but several others were very close to the limit. Generator No. 101's problem was with its strip chart recorder. The recorder should be repaired or replaced immediately since using a strip chart recorder with a 17-sec response time is a severe handicap in teaching people to "read" smoke.

SECTION 5

A NEED FOR FURTHER STUDY

CONCLUSIONS

Based on the findings of this survey, the following conclusions have been made:

1. Less than half of the transmissometers surveyed met all of the requirements set forth in the transmissometer design and performance specifications.

2. Significant differences existed in the "photopic comparison" of transmissometer photocells.

3. Some operators of "smoke school" generators were not adequately trained to properly calibrate their equipment.

4. The need was established for all "smoke school" transmissometers to be checked at regular intervals by the appropriate EPA Regional Office.

5. Other aspects of the visible emissions training effort such as stability and range of smoke opacities produced should also be investigated.

A RECOMMENDATION FOR A MORE COMPREHENSIVE VISIBLE EMISSIONS STUDY

A special study should be initiated to improve the training program for smoke inspectors. The following five-phase study should contribute significantly in bolstering the visible emissions training effort.

Phase 1 - State and Federal Visible Emissions Generator Survey

Before making any changes to the present program, a complete summary of what exists and how it is being used is necessary. A survey of all visible emissions training programs throughout the country would provide this important background information. This survey form should include:

- Location of generator
- Generator manufacturer
- Date generator manufactured
- Name of operator
- Type of location (portable or fixed)
- Checks for meeting Federal Register guidelines
- Number of schools per year
- Number of students trained per year
- Operator education in smoke reading
- Operator recommendations or complaints concerning generator design

With this information available, a national locator map and data file could be compiled.

Phase 2 - Evaluation of Factors Affecting Visible Emissions Training Programs

A look at normal problems that affect the successful outcome of training efforts should reveal ways that this training may be improved. Some of these problems are weather related. The effects of temperature extremes, rain, snow, wind, and light conditions on observer performance should be investigated. Specifically, the use of a 90°, laminar, elbow stack attachment in high wind conditions should be checked. Also, an evaluation of the effect of reading smoke against a variety of background features should be tested. Since some smoke inspectors have been known to record visible emissions readings from inside vehicles through closed windows, the feasibility of taking indoor readings through glass media should be studied. Finally, the design of the score sheets used to record opacity data should be investigated.

Phase 3 - Fuel Evaluation Study for Visible Emissions Generator Applications

With the classification of benzene as a hazardous pollutant, other fuels are being used to make black smoke. Although toluene has been the recommended replacement for benzene, other new fuels or hybrid fuels may be more applicable to visible emissions training. An evaluation of the alternate fuels for making black or white smoke could include a look at:

- Health hazards
- Burning characteristics
- Air flow requirements
- Plume color
- Particle size
- Stability
- Storage
- Burning rate vs. opacity
- Freezing point
- Safety aspects

The product of this evaluation would be the specification of fuels to be used by "smoke schools" for making black and white smoke.

Phase 4 - Development of a Better Visible Emissions Generator

After identifying the problems that are inherent with current smoke generators and the fuels that should be used to make smoke, the next step is to determine ways to improve smoke generator design and operation. Factors affecting performance that should be investigated include:

- Air flow stability and flow rate
- Black smoke chamber design
- Fuel flow transfer system
- Mechanical structure of stack and chamber
- Functional layout of control panels
- Power supply stability requirements
- Programmable opacity meter
- Fuel pump and regulator valve
- Photocell selection
- Light source
- Readout device
- Calibration procedures

With the information obtained from this investigation, a prototype generator can be built that would more nearly meet the needs of a visible emission training program. Developed along with the generator would be a comprehensive operators' manual that includes:

- Operating principles
- Method of operation
- Maintenance requirements
- Electrical schematics
- Guidelines for safe use
- Parts list

Phase 5 - Training Program for Visible Emissions Generator Operators

As the new generator developed in Phase 4 is marketed and gradually replaces current generators, a training program for generator operators will become essential. Such a program would need to be coordinated with existing programs in EPA's Air Pollution Training Institute. Included in the training program should be instructions on how to conduct an initial certification course as well as a recertification course. Also included should be an explanation of the legal aspects that pertain to the visible emissions operator. The operators should be taught the requirements for:

- Classroom instruction
- Record keeping
- Calibration
- Operation
- Maintenance
- Safety

The student operators should be given the opportunity to demonstrate:

- A general knowledge of the generator
- Maintenance of class control
- Operation of the visible emissions generator
- Certification requirements

Generator operators should also be expected to repeat this training program at regular intervals to insure an ongoing program to maintain working knowledge of the visible emissions training program.

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